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A Letter [illegible] Gentleman in the
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AN ESSAY ON The *Uſefulneſs* of MATHEMATICAL LEARNING, &c.

SIR,

I AM glad to hear from you, that the ſtudy of the *Mathematicks* is Promoted and Encouraged among the *Youth* of your *Univerſity*. The great influence, which theſe *Sciences* have on *Philoſophy* and all uſeful Learning, as well as the Concerns of the Publick, may ſufficiently recommend them to your choice and conſideration: and the particular advantages, which You of that place enjoy, give Us juſt reaſon to expect from You a ſuitable improvement in them. I have here ſent you ſome ſhort reflections upon the *Uſefulneſs* of *Mathematical Learning*, which may ſerve as an argument to incite you to a cloſer and more vigorous purſuit of it.

In all Ages and Countries, where Learning hath prevailed, the *Mathematical Sciences* have been looked upon as the moſt conſiderable branch of it. The very name Μάθησις implies no leſs; by which they were called either for their excellency, or becauſe of all the *Sciences* they were firſt taught, or becauſe they were judg'd to comprehend πάντα τὰ μαθήματα. And amongſt thoſe, that are commonly reckoned to be the ſeven Liberal Arts, four are Mathematical, to wit, *Arithmetick, Muſick, Geometry,* and *Aſtronomy.*

But notwithſtanding their Excellency and Reputation, they have not been taught nor ſtudy'd ſo univerſally, as ſome of the reſt; which I take to have proceeded from the following cauſes: The *averſion of the greateſt part of Mankind to ſerious attention and cloſe arguing;* Their *not comprehending ſufficiently the neceſſity or great uſefulneſs of theſe in other parts of Learning;* An *Opinion that this ſtudy requires a particular Genius and turn of Head, which few are ſo happy as to be Born with;* And *the want of Publick Encouragement, and able Maſters.* For theſe, and perhaps ſome other reaſons, this ſtudy hath been generally neglected, and regarded only by ſome few perſons whoſe happy Genius and Curioſity have prompted them to it, or who have been forced upon it by its immediate ſubſerviency to ſome particular Art or Office.

Therefore I think I cannot do better ſervice to Learning, Youth, and the Nation in general, than by ſhewing, *That the Mathematicks of all parts of humane Knowledge, for the improvement of the Mind, for their ſubſerviency to other Arts, and their uſefulneſs to the Common-wealth, deſerve moſt to be encouraged.* I know a diſcourſe of this nature will be offenſive to ſome, who, while they are ignorant of Mathematicks, yet think themſelves Maſters of all valuable Learning: but their diſpleaſure muſt not deterr me from delivering an uſeful truth.

The advantages which accrue to the Mind by *Mathematical* ſtudies conſiſt chiefly in theſe things:

1ſt. In accuſtoming it to *attention.* 2*dly.* In giving it a habit of *cloſe* and *demonſtrative reaſoning.* 3*dly.* In freeing it from *prejudice, credulity,* and *ſuperſtition.*

First, the Mathematicks make the Mind attentive to the objects, which it conſiders. This they do by entertaining it with a great variety of truths, which are delightful and evident, but not obvious. Truth is the ſame thing to the underſtanding, as Muſick to the ear, and Beauty to the eye. The purſuit of it does really as much gratify a natural faculty implanted in us by our wiſe Creator, as the pleaſing of our Senſes: only in the former caſe, as the Object and Faculty are more Spiritual, the delight is the more pure, free from the regret, turpitude, laſſitude, and intemperance, that commonly attend ſenſual pleaſures. The moſt part of other *Sciences* conſiſting only of probable reaſonings, the Mind has not where to fix; and wanting ſufficient principles to purſue its ſearches upon, gives them over as impoſſible. Again, as in *Mathematical inveſtigations* truth may be found, ſo it is not always *obvious:* This ſpurs the Mind, and makes it diligent and attentive. *In Geometria* (ſays Quinctilian, lib. I. cap. 10.) *partem fatentur eſſe utilem teneris ætatibus: agitari namque animos, atque acui ingenia, & celeritatem percipiendi venire inde concedunt.* And *Plato* (in *Repub. lib.* VII.) obſerves, that the Youth, who are furniſhed with *Mathematical* knowledge, are prompt and quick at all other *Sciences,* εἰς πάντα τὰ Μαθήματα ὀξεῖς φαίνονται. Therefore he calls it [illegible] [illegible]. And indeed Youth is generally ſo much more delighted with *Mathematical* ſtudies, than with the unpleaſant tasks, that are ſome times impoſed upon them, that I have known ſome reclaimed by them from idleneſs and neglect of learning, and acquire in time a habit of thinking,

ing, diligence, and attention; qualities, which we ought to ſtudy by all means to beget in their deſultory and roving Minds.

The ſecond advantage, which the Mind reaps from *Mathematical* knowledge, is a habit of *clear, demonſtrative,* and *methodical* Reaſoning. We are contriv'd by Nature to learn by Imitation more than by Precept: And I believe in that reſpect Reaſoning is much like other inferiour Arts (as *Dancing, Singing,* &c.) acquired by practice. By accuſtoming our ſelves to Reaſon cloſely about quantity, we acquire a habit of doing ſo in other things. It is ſurprizing to ſee, what ſuperficial, inconſequential Reaſonings, ſatisfy the moſt part of Mankind. A piece of wit, a jeſt, a ſimile, or a quotation of an Author, paſſes for a mighty Argument: with ſuch things as theſe are the moſt part of Authors ſtuffed; and from theſe weighty premiſes they infer their concluſions. This weakneſs and effeminacy of Mankind in being perſwaded where they are delighted, have made them the ſport of Orators, Poets, and Men of wit. Thoſe *lumina Orationis* are indeed very good diverſion for the Fancy, but are not the proper buſineſs of the Underſtanding; and where a Man pretends to write on abſtract ſubjects in a Scientifical method, he ought not to debauch in them. Logical precepts are more uſeful, nay, they are abſolutely neceſſary for a rule of formal arguing in publick diſputations, and confounding an obſtinate and perverſe adverſary, and expoſing him to the audience, or readers. But in the ſearch of truth, an imitation of the method of the *Geometers* will carry a Man further than all the *Dialectical* rules. Their *Analyſis* is the proper model we ought to form our ſelves upon, and imitate in the regular diſpoſition and gradual progreſs

greſs

eſs of our enquiries; and even he, who is ig-
orant of the nature of *Mathematical Analyſis*,
es a method ſomewhat Analogous to it. The
mpoſition of the *Geometers*, or their method of
emonſtrating truths already found out, viz. *by*
finitions of words agreed upon, by Self-evident
ths, and Propoſitions that have been already demon-
ated, is practicable in other ſubjects, tho' not
the ſame perfection, the natural want of evi-
nce in the things themſelves not allowing it;
t it is imitable to a conſiderable degree. I dare
peal to ſome writings of our own Age and Na-
n, the Authors of which have been Mathe-
tically inclined. I ſhall add no more on this
d, but that one, who is accuſtomed to the
thodical Syſtems of truths, which the *Geometers*
ve reared up in the ſeveral branches of thoſe
ences, which they have cultivated, will hardly
ar with the confuſion and diſorder of other
ences, but endeavour as far as he can to re-
m them.

Thirdly, *Mathematical* knowledge adds a manly
our to the Mind, frees it from *prejudice*, *cre-*
ity, and *ſuperſtition*. This it does two ways,
. by accuſtoming us to examine, and not to
ke things upon truſt. 2*dly*. By giving us a
ar and extenſive knowledge of the Syſtem of
World; which, as it creates in us the moſt
ofound reverence of the Almighty and wiſe
eator; ſo it frees us from the mean and narrow
oughts, which ignorance and ſuperſtition are
to beget. How great an Enemy *Mathematicks*
e to ſuperſtition, appears from this, That in
oſe Countries, where *Romiſh Prieſts* exerciſe
eir barbarous Tyranny over the Minds of Men,
ronomers, who are fully perſwaded of the mo-
on of the Earth, dare not ſpeak out: But tho'

the *Inquiſition* may extort a Recantation, th Pope and a general Council too will not fin themſelves able to perſwade to the contrary Op nion. Perhaps this may have given occaſion t a calumnious ſuggeſtion, as if *Mathematicks* w an enemy to Religion, which is a ſcandal thro both on the one and the other; for truth ca never be an enemy to true Religion, which ap pears always to the beſt advantage, when it most examined.

——Si propius ſtes,
Te capiet magis.——

On the contrary, the *Mathematicks* are friend to Religion; inaſmuch as they charm the paſſion reſtrain the impetuoſity of imagination, and purg the Mind from error and prejudice. Vice error, confuſion and falſe Reaſoning; and truth is more or leſs oppoſite to it. Beſides *Ma thematical* ſtudies may ſerve for a pleaſant ente tainment for thoſe hours, which young Men ar apt to throw away upon their Vices; the de lightfulneſs of them being ſuch, as to make ſoli tude not only eaſy, but deſirable.

What I have ſaid may ſerve to recommen *Mathematicks* for acquiring a vigorous Conſtitu tion of Mind; for which purpoſe they are uſeful, as exerciſe is for procuring Health an Strength to the Body. I proceed now to ſhe their vaſt extent and Uſefulneſs in other parts knowledge. And here it might ſuffice to tell yo that *Mathematicks* is the *Science* of quantity, the *Art* of Reaſoning about things that are cap ble of *more* and *leſs*, and that the moſt part the objects of our knowledge are ſuch: as matte ſpace, number, time, motion, gravity, *&c.* W have but imperfect ideas of things without quan tity, and as imperfect a one of quantity it ſe

with

without the help of *Mathematicks*. All the viſible works of God Almighty are made in *number*, *weight*, and *meaſure*; therefore to conſider them, we ought to underſtand *Arithmetick*, *Geometry*, and *Staticks*: and the greater advances we make in thoſe Arts, the more capable we are of conſidering ſuch things, as are the ordinary objects of our Conceptions. But this will farther appear from particulars.

And firſt, if we conſider, to what perfection we now know the Courſes, Periods, Order, Diſtances, and Proportions of the ſeveral great Bodies of the Univerſe, at leaſt ſuch as fall within our view; we ſhall have cauſe to admire the Sagacity and Induſtry of the *Mathematicians*, and the power of *Numbers* and *Geometry* well apply'd. Let us caſt our Eyes backward, and conſider *Aſtronomy* in its Infancy: or rather let us ſuppoſe it ſtill to begin: for inſtance, a Colony of Rude Country people, tranſplanted into an Iſland remote from the Commerce of all Mankind, without ſo much as the knowledge of the Kalendar, and the Periods of the Seaſons, without Inſtruments to make Obſervations, or any the leaſt notion of Obſervations or Inſtruments. When is it, we could expect any of their poſterity ſhould arrive at the Art of predicting an Eclipſe? Not only ſo, but the Art of reckoning all Eclipſes that are paſt or to come, for any number of Years? When is it, we could ſuppoſe, that one of thoſe Iſlanders tranſported to any other place of the Earth, ſhould be able by the inſpection of the Heavens to find how much he were South or North, Eaſt or Weſt of his own Iſland, and to conduct his Ship back thither? For my part, tho' I know this may be, and is daily done, by what is known in *Aſtronomy*; yet when I conſider the vaſt Induſtry, Sagacity, multitude of Obſervations, and other extrinſick things neceſſary for ſuch a ſublime piece of knowledge, I ſhould be apt to pronounce it impoſſible, and never to be hoped for. Now we are let ſo much into the knowledge of the Machine of the Univerſe, and motion of its parts by the Rules of this *Science*, perhaps the invention may ſeem eaſy. But when we reflect, what Penetration and Contrivance were neceſſary to lay the foundations of ſo great and extenſive an Art, we cannot but admire its firſt Inventors: as *Thales Mileſius*, who, as *Diogenes Laertius* and *Pliny* ſay, firſt predicted Eclipſes; and his Scholar *Anaximander Mileſius*, who found out the Globous Figure of the Earth, the Æquinoctial Points, the Obliquity of the Ecliptick, the principles of Gnomonicks, and made the firſt Sphere or Image of the Heavens; and *Pythagoras*, to whom we owe the diſcovery of the true Syſtem of the World, and order of the Planets. Tho' it may be, they were aſſiſted by the *Egyptians* and *Chaldeans*. But whoever they were, that firſt made theſe bold ſteps in this Noble Art, they deſerve the praiſe and admiration of all future Ages.

Felices animæ, quibus hæc cognoſcere primis,
Inque domos ſuperas ſcandere cura fuit.
Credibile eſt illos pariter vitiiſque jociſque
Altius humanis exſeruiſſe caput.
Non Venus & vinum ſublimia pectora fregit,
Officiumque fori, militiæque labor.
Non levis ambitio, perfuſaque gloria fuco,
Magnarumque fames ſollicitavit opum.
Admovere oculis diſtantia ſidera noſtris,
Ætheraque ingenio ſuppoſuere ſuo.

Ovid. in I°. Faſt.

But tho' the induſtry of former Ages had diſcover'd the Periods of the great Bodies of the Univerſe, and the true Syſtem and Order of them, and their Orbits pretty near; yet was there one thing ſtill reſerved for the glory of this Age, and the honour of the *Engliſh Nation*, The grand ſecret of the whole Machine; which, now it is diſcover'd, proves to be (like the other contrivances of Infinite Wiſdom) ſimple and natural, depending upon the moſt known and moſt common property of matter, viz. *gravity*. From this the incomparable Mr. *Newton* has demonſtrated the Theories of all the Bodies of the Solar Syſtem, of all the primary Planets and their ſecondaries, and among others, the Moon, which ſeem'd moſt averſe to numbers: And not only of the Planets, the ſloweſt of which compleats its Period in leſs than half the Age of a Man, but likewiſe of the Comets, ſome of which its probable ſpend more than 2000. years in one Revolution about the Sun; for whoſe Theory he has laid ſuch a foundation, that after Ages aſſiſted with more Obſervations, may be able to Calculate their returns. In a word, the preceſſion of the Æquinoctial Points, the Tydes, the unequal Vibration of Pendulous Bodies in different Latitudes, *&c.* are no more a Queſtion to thoſe, that have *Geometry* enough to underſtand, what he has delivered on thoſe Subjects: A perfection in *Philoſophy*, that the boldeſt Thinker durſt hardly have hoped for; and, unleſs Mankind turn barbarous, will continue the Reputation of this Nation, as long as the Fabrick of Nature ſhall endure. After this, what is it, we may not expect from *Geometry* join'd to *Obſervations* and *Experiments*?

The next conſiderable object of Natural knowledge, I take to be *Light*. How unſucceſsful enquiries are about this Glorious Body without the help of *Geometry*, may appear from the empty and frivolous diſcourſes and diſputations of a ſort of Men, that call themſelves *Philoſophers*; whom nothing will ſerve forſooth, but the knowledge of the very Nature, and intimate Cauſes of every thing: while on the other hand, the *Geometers* not troubling themſelves with thoſe fruitleſs enquiries about the *Nature* of *Light*, have diſcover'd two remarkable properties of it, in the reflection and refraction of its beams: and from thoſe, and their ſtreightneſs in other caſes, have invented the noble Arts of *Opticks*, *Catoptricks*, and *Dioptricks*; teaching us to manage this ſubtile Body for the improvement of our knowledge, and uſeful purpoſes of Life. They have likewiſe demonſtrated the cauſes of ſeveral Cœleſtial appearances, that ariſe from the inflection of its Beams, both in the Heavenly Bodies themſelves and other Phœnomena, as *Parhelia*, the *Iris*, &c. and by a late Experiment they have diſcover'd the celerity of its motion. And we ſhall know yet more ſurprizing properties of *Light*, when Mr. *Newton* ſhall be pleas'd to gratify the World with his *Book of Light and Colours*.

The *Fluids* which involve our Earth, viz. *Air* and *Water*, are the next great and conſpicuous Bodies, that Nature preſents to our view: And I think we know little of either, but what is owing to *Mechanicks* and *Geometry*. The two chiefeſt properties of *Air*, its Gravity and Elaſtick force, have been diſcover'd by Mechanical Experiments. From thence the decreaſe of the Air's denſity according to the increaſe of the diſtance of the Earth has been demonſtrated by *Geometers*, and confirmed by Experiments of the ſubſidence of the *Mercury* in the *Torricellian Experiment*. From this likewiſe, by aſſiſtance of *Geometry*, they have determined the height of the Atmoſphere, as far as it has any ſenſible denſity; which agrees exactly with another Obſervation of the duration f the Twilight. *Air* and *Water* make up the bjeƈt of the *Hydroſtaticks*, tho' denominated only rom the latter, of which the principles were ong ſince ſettled and demonſtrated by *Archimedes*, n his Book περὶ τῶν ὀχουμένων, where are demonſtrated the cauſes of ſeveral ſurprizing Phœnomena of Nature, depending only on the *Æquilibrium* of *Fluids*, the relative Gravities of theſe *Fluids*, and of Solids ſwimming or ſinking thereſn. Here alſo the Mathematicians conſider the ifferent Preſſures, Reſiſtances, and Celerities of olids moved in Fluids: from whence they explain a great many appearances of Nature, unintelligible to thoſe who are ignorant of *Geometry*.

Next, if we deſcend to the *Animal Kingdom*, here we may ſee the brighteſt ſtrokes of Divine Mechanicks. And whether we conſider firſt the *nimal Oeconomy* in general, either in the internal motion and circulation of the Juices forced hrough the ſeveral Canals by the motion of the Heart, or their external motions, and the Inſtruments wherewith theſe are performed, we muſt educe them to Mechanical Rules, and confeſs he neceſſity of the knowledge of Mechanicks to nderſtand them, or explain them to others. *Borelli* in his excellent Treatiſe *de motu Animalium*, *Steno* in his admirable *Myologiæ ſpecimen*, and ther Mathematical Men on the one hand, and the nonſenſical, unintelligible ſtuff that the common Writers on theſe Subjeƈts have filled their Books with on the other, are ſufficient inſtances to ſhew, how neceſſary *Geometry* is in ſuch ſpeculations. The only Organ of an Animal Body, whoſe ſtructure and manner of operation is fully underſtood, has been the only one, which the *Geometers* have taken to their ſhare to conſider. It's incredible, how ſillily the greateſt and ableſt Phyſicians talked of the parts of the Eye and their uſe, and of the *modus viſionis*, before *Kepler* by his *Geometry* found it out, and put it paſt diſpute, tho' they apply'd themſelves particularly to this, and valued themſelves on it: and *Galen* pretended a particular Divine Commiſſion to treat of it. Nay, notwithſtanding the full diſcovery of it, ſome go on in copying their Predeceſſors, and talk as *Ungeometrically* as ever. It's true, we cannot reaſon ſo clearly of the internal motions of an Animal Body, as of the external, wanting ſufficient *data* and deciſive Experiments: But what relates to the latter (as the Articulation, Structure, Inſertion, and *Vires* of the Muſcles) is as Subject to ſtrict Mathematical diſquiſition, as any thing whatſoever; and even in the Theory of Diſeaſes and their Cures, thoſe, who talk Mechanically talk moſt intelligibly. Which may be the reaſon for the Opinion of the ancient Phyſicians, that Mathematicks are neceſſary for the ſtudy of Medicine it ſelf, for which I could bring long quotations out of their Works. Among the Letters that are aſcrib'd to *Hippocrates*, there is one to his Son *Theſſalus*, recommending to him the ſtudy of *Arithmetick* and *Geometry*, as neceſſary to Medicine. *Galen* in his Book intituled ὅτι ἄριστος ἰατρὸς καὶ φιλόσοφος, begins, Οἷόν τι πεπόνθασιν οἱ πολλοὶ τῶν ἀθλητῶν, ἐπιθυμοῦντες μὲν Ὀλυμπιονῖκαι γενέσθαι, μηδὲν δὲ πράττειν, ὡς τούτου τυχεῖν, ἐπιτηδεύοντες, τοιοῦτόν τι καὶ τοῖς πολλοῖς τῶν ἰατρῶν συμβέβηκεν· ἐπαινοῦσι μὲν γὰρ Ἱπποκράτην καὶ πρῶτον ἁπάντων ἡγοῦνται· γενέσθαι δ' αὐτοὺς ἐν ὁμοίοις ἐκείνῳ πάντα μᾶλλον ἢ τοῦτο πράττουσι. ὁ μὲν γὰρ οὐ μικρὰν μοῖραν, εἰς ἰατρικὴν φησὶ συμβάλλεσθαι τὴν ἀστρονομίαν,

ίαν, ϗ δηλονότι, τὴν ταύτης ἡγεμόνα ἐξ ἀνάγκης Γεωμε-
ρίαν. οἱ δ' ὐ μόνον αὐτοὶ μετέρχονται τέτων ὐδέτερον, ἀλλὰ
ϗ τοῖς μετιοῦσι μέμφονται. If one of the reaſons of
he Ancients for this be now ſomewhat unfaſhion-
ble, to wit, becauſe they thought a Phyſician
ould be able to know the ſituation and aſpects
f the Stars, which they believed had influence
pon Men and their Diſeaſes, (and poſitively to
eny it, and ſay, that they have none at all, is
e effect of want of Obſervation) we have a much
etter and undoubted one in its room; *viz.* That
athematicks are found to be the beſt Inſtru-
ent of promoting natural knowledge. 2*dly.* If
e conſider, not only the Animal Oeconomy in
neral, but likewiſe the wonderful ſtructure of
e different ſorts of Animals, according to the
fferent purpoſes for which they were deſign'd,
e various Elements they inhabit, the ſeveral
ays of procuring their nouriſhment, and pro-
gating their kind, the different enemies they
ve, and accidents they are ſubject to, here is
l a greater need of *Geometry.* It is pity, that
e qualities of an expert *Anatomiſt* and skilful
ometer have ſeldom met in the ſame perſon.
hen ſuch a one ſhall appear, there is a whole
rra incognita of delightful knowledge to employ
time, and reward his induſtry.

As for the other two Kingdoms; *Borelli* and
her *Mathematical Men,* ſeem to have talked very
early of *Vegetation:* and *Steno* another Mathe-
atician, in his excellent Treatiſe *de Solido intra*
lidum naturaliter contento, has apply'd this part
learning very handſomely to *Foſſils* and ſome
her parts of Natural Hiſtory. I ſhall add only
e thing more, That if we conſider motion it
lf, the great Inſtrument of the Actions of Bo-
ies upon one another, the Theory of it is en-

tirely owing to the *Geometers*; who have demonſtrated its Laws both in hard and elaſtick Bodies; ſhew'd how to meaſure its quantity, how to compound and reſolve the ſeveral forces, by which Bodies are agitated, and to determine the *Lines*, which thoſe compound forces make them deſcribe: of ſuch forces gravity, being the moſt conſtant and uniform, affords a great variety of uſeful knowledge, in conſidering ſeveral motions that happen upon the Earth; *viz.* As to the free deſcent of heavy Bodies; The curve of projectiles; The deſcent and weight of heavy Bodies when they lie on inclined plains; The Theory of the motion of Pendulous Bodies, *&c.*

From what I have ſaid, I ſhall draw but one Corollary, That a natural Philoſopher without Mathematicks is a very odd ſort of a perſon, that reaſons about things that have *Bulk*, *Figure*, *Motion*, *Number*, *Weight*, &c. without *Arithmetick*, *Geometry*, *Mechanicks*, *Staticks*, &c. I muſt needs ſay, I have the laſt Contempt for thoſe Gentlemen, that pretend to explain how the Earth was framed, and yet can hardly meaſure an Acre of Ground upon the ſurface of it: And as the Philoſopher ſpeaks, *Qui repente pedibus illotis ad Philoſophos divertunt, non hoc eſt ſatis, quod ſint omnino* ἀθεώρητοι, ἄμουσοι, ἀγεωμέτρητοι, *ſed legem etiam dant, quâ Philoſophari diſcant.*

The uſefulneſs of *Mathematicks* in ſeveral other Arts and Sciences is fully as plain. They were looked upon by the ancient Philoſophers as the key to all knowledge. Therefore *Plato* wrote upon his School, Οὐδεὶς ἀγεωμέτρητος εἰσίτω, *Let none unskilled in Geometry enter*; and *Xenocrates* told one ignorant in *Mathematicks*, who deſired to be his Scholar, that he was fitter to Card Wooll, λαβὰς γὰρ οὐκ ἔχεις φιλοσοφίας, *you want the handle of*

Philoſophy, viz. *Geometry*. There is no underſtand-
ing the works of the ancient Philoſophers without
it. *Theo Smyrnæus* has wrote a Book entituled,
An explanation of thoſe things in Mathematicks,
hat are neceſſary for the reading of *Plato*: *Ariſto-*
le illuſtrates his precepts and other thoughts by
Mathematical examples, and that not only in *Lo-*
ick, &c. but even in *Ethicks*, where he makes
uſe of Geometrical and Arithmetical proportion,
o explain commutative and diſtributive juſtice.

Every body knows, that *Chronology* and *Geogra-*
hy are indiſpenſable preparations for Hiſtory: a
elation of matter of fact being a very lifeleſs in-
pid thing without the circumſtances of time and
lace. Nor is it ſufficient for one, that would
nderſtand things thoroughly, that he knows the
Topography, that is, the name of the Country,
where ſuch a place lies, with thoſe of the near
djacent places, and how theſe lie in reſpect of
ne another; but it will become him likewiſe to
nderſtand the Scientifical principles of the Art:
hat is, to have a true Idea of a place, we ought
know the relation it has to any other place,
to the diſtance and bearing, its Climate, Heat,
Cold, length of days, &c. which things do much
nliven the Reader's notion of the very action it
lf. Juſt ſo, it is neceſſary to know the Tech-
cal or Doctrinal part of Chronology, if a Man
ould be thoroughly ſkill'd in Hiſtory, it being
mpoſſible without it, to unravel the confuſion of
iſtorians. I remember Mr. *Hally* has determin'd
e day and hour of *Julius Cæſar's* Landing in
ritain, from the circumſtances of his relation.
nd every body knows, how great uſe our in-
omparable Hiſtorian Mr. *Dodwell* has made of
he Calculated times of Eclipſes, for ſettling the
imes of great Events, which before were as to

this eſſential circumſtance almoſt fabulous. Both *Chronology* and *Geography*, and alſo the knowledge of the Sun's and Moon's motions, ſo far as they relate to the conſtitution of the Kalendar and Year, are neceſſary to a Divine, and how ſadly ſome otherwiſe Eminent have blunder'd, when they meddled with things that relate to theſe, and border on them, is too apparent.

No body, I think, will queſtion the intereſt, that Mathematicks have in *Painting*, *Muſick*, and *Architecture*, which are all founded on Numbers. Perſpective and the Rules of Light and Shadows are owing to *Geometry* and *Opticks*: And I think thoſe two comprehend pretty near the whole Art of *Painting*, except *decorum* and *ordinance*; which are only a due obſervance of the Hiſtory and Circumſtances of the ſubject, you repreſent. For by Perſpective, may be underſtood the Art of deſigning the outlines of your ſolid, whether that be a Building, Landskip, or Animal: and the draught of a Man is really as much the Perſpective of a Man, as the draught of a Building is of a Building; tho' for particular reaſons, as becauſe it conſiſts of more crooked lines, *&c.* it is hard to reduce the Perſpective of the former, to the ordinary eſtabliſhed Rules.

If *Mathematicks* had not reduced *Muſick* to a regular Syſtem, by contriving its *Scales*, it had been no Art, but Enthuſiaſtick Rapture, left to the roving fancy of every Practitioner. This appears by the extraordinary pains, which the Ancients have taken to fit numbers to three ſorts of Muſick, the *Diatonick*, *Chromatick*, and *Enharmonick*: which if we conſider with their nicety in diſtinguiſhing their ſeveral *Modes*, we ſhall be apt to judge, they had ſomething very fine in their *Muſick*, at leaſt for moving the paſſions with ſingle

Inſtruments and Voices. But *Muſick* had been imperfect ſtill, had not *Arithmetick* ſtepped in once more, and *Guido Aretinus* by inventing the temperament, making the Fifth falſe by a certain determined quantity, taught us to Tune our Organs, and intermix all the three kinds of the Ancients, to which we owe all the Regular and Noble Harmony of our modern *Muſick*.

As for *Civil Architecture* (of Military I ſhall ſpeak afterwards) there is hardly any part of *Mathematicks*, but is ſome way ſubſervient to it. *Geometry* and *Arithmetick* for the due meaſure of the ſeveral parts of a Building, the Plans, Models, Computation of Materials, time and charges: for ordering right its Arches and Vaults, that they may be both firm and beautiful: *Mechanicks* for its ſtrength and firmneſs, tranſporting and raiſing materials: and *Opticks* for the Symmetry and Beauty. And I would not have any aſſume the Character of an *Architect* without a competent skill in all of theſe. You ſee that *Vitruvius* requires theſe and many more for making a compleat *Architect*. I muſt own, that ſhould any one ſet up to practice in any of the fore-mentioned Arts, furniſhed only with his Mathematical Rules, he would produce but very clumſy pieces. He, that ſhould pretend to draw by the Geometrical Rules of Perſpective, or Compoſe *Muſick* meerly by his ſkill in Harmonical numbers, would ſhew but aukward performances. In thoſe Compos'd Subjects, beſides the ſtiff Rules, there muſt be Fancy, Genius, and Habit. Yet nevertheleſs theſe Arts owe their being to *Mathematicks*, as laying the foundation of their Theory, and affording them Precepts, which being once invented, are ſecurely rely'd upon by Practitioners. Thus many deſign, that know not a tittle of the reaſon of the Rules, they practice by; and many no better qualify'd in their way Compoſe *Muſick*, better perhaps than he could have done, that invented the *Scale*, and the *Numbers* upon which their Harmony is founded. As *Mathematicks* laid the foundation of theſe Arts, ſo they muſt improve them: and he, that would invent, muſt be skill'd in Numbers, beſides it is fit a Man ſhould know the true grounds and reaſons of what he ſtudies: and he that does ſo, will certainly practice in his Art with greater judgment and variety, where the ordinary Rules fail him.

I proceed now to ſhew the more immediate uſefulneſs of *Mathematicks* in *Civil Affairs.* To begin with *Arithmetick,* it were an endleſs task to relate its ſeveral uſes in publick and private buſineſs. The regulation and quick diſpatch of both, ſeem intirely owing to it. The Nations, that want it, are altogether barbarous, as ſome *Americans,* who can hardly reckon above twenty. And I believe it would go near to ruine the Trade of the Nation, were the eaſy practice of *Arithmetick* aboliſhed: for example, were the Merchants and Tradeſmen oblig'd to make uſe of no other than the *Roman* way of notation by Letters, inſtead of our preſent. And if we ſhould feel the want of our *Arithmetick* in the eaſieſt Calculations, how much more in thoſe, that are ſome thing harder; as Intereſt ſimple and compound, Annuities, *&c.* in which, it is incredible, how much the ordinary Rules and Tables influence the diſpatch of buſineſs. *Arithmetick* is not only the great Inſtrument of private Commerce, but by it are (or ought to be) kept the publick Accounts of a Nation: I mean thoſe, that regard the whole State of a Common-wealth, as to the number, fructification of its people, increaſe of Stock, improve-

ment of Lands and Manufactures, Ballance of
Trade, Publick Revenues, Coynage, Military
ower by Sea and Land, &c. Thoſe, that would
udge or reaſon truly about the State of any Na-
on, muſt go that way to work, ſubjecting all
e fore-mentioned particulars to Calculation.
his is the true *Political* knowledge. In this
eſpect the affairs of a Common-wealth differ
om thoſe of a private Family, only in the great-
eſs and multitude of particulars, that make up
e accounts. *Machiavel* goes this way to work
his account of different Eſtates. What Sir
illiam Petty and ſeveral others of our Country-
en have wrote in *Political Arithmetick*, does a-
ndantly ſhew the pleaſure and uſefulneſs of ſuch
eculations. It is true, for want of good in-
rmation, their Calculations ſome times proceed
on erroneous ſuppoſitions: but that is not the
ult of the Art. But what is it, the Govern-
ent could not perform in this way, who have
command of all publick Records?

Laſtly, Numbers are applicable even to ſuch
ngs, as ſeem to be govern'd by no rule, I mean
ch as depend on *Chance:* The quantity of pro-
bility and proportion of it in any two propoſed
es being ſubject to Calculation as much as any
ng elſe. Upon this depend the principles of
me. We find Sharpers know enough of this,
cheat ſome men that would take it very ill to
thought Bubbles: And one Gameſter exceeds
other, as he has a greater ſagacity and readi-
ſs in Calculating his probability to win or loſe
any propoſed caſe. To underſtand the Theory
Chance throughly, requires a great knowledge
Numbers, and a pretty competent one of
gebra.

The ſeveral uſes of *Geometry* are not much fewer than thoſe of *Arithmetick*. It is neceſſary for aſcertaining of property both in Plains and Solids, or in Surveying and Gauging. By it Land is ſold by the meaſure as well as Cloth: Work-men are pay'd the due price of their labour, according to ſuperficial or ſolid meaſure of their work: and the quantity of liquors determined for a due regulation of their price and duty. All which do wonderfully conduce to the eaſy diſpatch of buſineſs, and the preventing of frauds and controverſies. I need not mention the Meaſuring diſtances, laying down of Plans and Maps of Countries, in which we have daily Experience of its uſefulneſs. Theſe are ſome familiar inſtances of things, to which *Geometry* is ordinarily apply'd: of its uſe in *Civil*, *Military*, and *Naval Architecture* we ſhall ſpeak afterwards.

From *Aſtronomy* we have the regular diſpoſition of our time, in a due ſucceſſion of years, which are kept within their limits as to the return of the Seaſons, and the motion of the Sun. This is no ſmall advantage for the due repetition of the ſame work, Labour and Actions. For many of our Publick, Private, Military, and Country Affairs, Appointments, &c. depending on the products of the Ground, and they on the Seaſons; It is neceſſary, that the returns of them be adjuſted pretty near to the motion of the Sun: and we ſhould quickly find the inconveniency of a *vagu* undetermined year, if we uſed that of the *Mahumetans*, whoſe beginning and every month wanders through all the days of ours or the Solar year, which ſhews the Seaſons. Beſide, the adjuſting of the Moon's motion to the Sun's is required for the decent Obſervation and Celebration of the *Church-Feaſts* and *Faſts* according to the he Ancient Cuſtom and Primitive Inſtitution; nd likewiſe for the knowing of the Ebbing and Flowing of the Tides, the Spring and Neap Tides, Currents, &c. So that what-ever ſome ople may think of an *Almanack* where all theſe e ſet down, it is oftentimes the moſt uſeful paper at is publiſhed the ſame year with it: Nay, the ation could better ſpare all the Voluminous uthors in the *Term-Catalogue*, than that ſingle eet. Beſides, without a regular Chronology, ere can be no certain Hiſtory; which appears the confuſion amongſt Hiſtorians before the ht diſpoſition of the year, and at preſent among *Turks*, who have the ſame confuſion in their ſtory as in their Kalendar. Therefore a Mat- of ſuch importance might well deſerve the care the *Great Emperour*, to whom we owe our pre- nt Kalendar; who was himſelf a great proficient *Aſtronomy*. *Pliny* has quoted ſeveral things om his Books of the *Riſing* and *Setting* of the ars, *Lib.* XVIII. *cap.* 25, 26, &c. and *Lucan* kes him ſay,

——Media inter prælia ſemper
Stellarum, Cœlique plagis, ſuperiſque vacavi.

The *Mechanicks* have produced ſo many uſeful gines, ſubſervient to conveniency, that it would a task too great to relate the ſeveral ſorts of em: ſome of them keep Life it ſelf from being burden. If we conſider ſuch, as are invented raiſing weights, and are employ'd in Building d other great works, in which no impediment too great for them; or *Hydraulick* Engines for iſing of Water, ſerving for great uſe and com- rt to Mankind, where they have no other way be ſupply'd readily with that neceſſary Element; ſuch as, by making Wind and Water work for us, ſave Animal force and great charges, and perform thoſe Actions, which require a vaſt multitude of hands, and without which every Man's time would be too little to prepare his own Aliment and other neceſſaries; or thoſe Machines, that have been invented by Mankind for delight and curioſity, imitating the motions of Animals, or other works of Nature; we ſhall have reaſon to admire and extol ſo excellent an Art. What ſhall we ſay of the ſeveral Inſtruments, which are contriv'd to meaſure time? We ſhould quickly find the value of them, if we were reduced to the condition of thoſe barbarous Nations, that want them. The *Pendulum-Clock* invented and compleated by that famous *Mathematician* Monſieur *Hugens* is an uſeful invention. Is there any thing more wonderful than ſeveral *Planetary Machines*, which have been invented to ſhew the motions of the Heavenly Bodies, and their places at any time? Of which the moſt Ingenious, according to the exacteſt Numbers and true Syſtem, was made by the ſame M. *Hugens:* to which we may very juſtly apply *Claudian's* noble Verſes upon that of *Archimedes.*

Jupiter in parvo cum cerneret Æthera vitro,
Riſit, & ad ſuperos talia dicta dedit:
Huccine mortalis progreſſa potentia curæ?
Jam meus in fragili luditur orbe labor.
Jura poli, rerumque fidem, legeſque Deorum
Ecce Syracuſius tranſtulit arte ſenex.
Incluſus variis famulatur ſpiritus aſtris,
Et vivum certis motibus urget opus.
Percurrit proprium mentitus ſignifer annum,
Et ſimulata novo Cynthia menſe redit.
Jamq; ſuum volvens audax induſtria mundum
Gaudet, & humana ſidera mente regit.

Qui

Quid falſo inſontem tonitru Salmonea miror?
Æmula naturæ parva reperta manus.

Here I ought to mention the *Sciatherical* Inſtru-
ents; for want of which there was a time, when
e *Grecians* themſelves were forced to meaſure
e Shadow, in order to know the Hour; and as
liny (*cap. ult. lib.* VII.) tells us, the *Romans* made
e of an erroneous Sun-dial for ninety nine years,
l *Q. Marcius Philippus* their Cenſor ſet up a bet-
r; which no doubt at that time was thought a
wel. And at laſt, that famous Pyramid was
up in the *Campus Martius*, to ſerve for a Gno-
n to a Dial marked on the ſtreet. To this ſort
Engines ought to be referred *Spheres*, *Globes*,
rolabes, *Projections of the Sphere*, &c. Theſe are
ch uſeful and neceſſary things, that alone may
commend the Art, by which they are made.
r by theſe we are able in our Cloſet to judge of
e Celeſtial motions, and to viſit the moſt diſtant
ces of the Earth, without the fatigue and dan-
of Voyages; to determine concerning their
ſtance, Situation, Climate, Nature of the Sea-
s, length of their days, and their relation to
e Celeſtial Bodies, as much as if we were In-
bitants. To all theſe I might add thoſe Inſtru-
nts, which the *Mathematicians* have invented to
ecute their own precepts, for making *Obſerva-*
ns either at Sea or Land, *Surveying*, *Gauging*, &c.
The *Catoptricks* and *Dioptricks* furniſh us with
riety of uſeful inventions, both for the pro-
oting of knowledge, and the conveniencies of
ife; whereby Sight, the great Inſtrument of
r perception, is ſo much improv'd, that neither
e diſtance, nor the minuteneſs of the Object
e any more impediments to it. The *Teleſcope*
of ſo vaſt uſe, that beſides the delightful and

uſeful purpoſes it is apply'd to here below, as the deſcrying Ships, and Men, and Armies at a diſtance, we have by its means diſcovered new parts of the Creation, freſh inſtances of the ſurprizing Wiſdom of the Adorable Creator. We have by it diſcovered the *Satellites* of *Jupiter*, the *Satellites* and *Ring* of *Saturn*, the Rotation of the Planets about their own Axes; beſides other appearances, whereby the Syſtem of the World is made plain to *ſenſe*, as was before to *reaſon*. The *Teleſcope* has alſo improv'd the manner of *Aſtronomical Obſervations*, and made them much more accurate, than it was poſſible for them to be before. And theſe improvements in *Aſtronomy*, have brought along with them (as ever) correſpondent improvements in *Geography*. From the Obſervation of *Jupiter's Satellites*, we have a ready way to determine the Longitude of places on the Earth. On the other hand, the *Microſcope* has not been leſs uſeful in helping us to the ſight of ſuch Objects, as by their minuteneſs eſcape our naked eye. By it Men have purſued Nature into its moſt retir'd receſſes; ſo that now it can hardly any more hide its greateſt Myſteries from us. How much have we learned by the help of the *Microſcope* of the contrivance and ſtructure of Animal and Vegetable Bodies, and the compoſition of Fluids and Solids? But if theſe *Sciences* had never gone further, than by their ſingle *Specula* and *Lentes* to give thoſe ſurprizing appearances of Objects and their Images, and to produce heat unimitable by our hotteſt Furnaces, and to furniſh infallible, eaſy, cheap, and ſafe remedies for the decay of our Sight ariſing commonly from old Age, and for purblindneſs, they had merited the greateſt eſteem, and invited to the cloſeſt ſtudy: eſpecially if we conſider, that ſuch as naturally are almoſt blind, and either know not their neareſt acquaintance at the diſtance of a rooms breadth, or cannot read in order to paſs their time pleaſantly, are by Glaſſes adapted to the defect of their Eyes ſet on a level again with thoſe that enjoy their Eye-ſight beſt, and that without danger, pain, or charge.

Again, *Mathematicks* are highly ſerviceable to a Nation in *Military Affairs*. I believe this will be readily acknowledg'd by every body. The Affairs of War take in Number, Space, Force, Diſtance, Time, *&c.* (things of *Mathematical* conſideration) in all its parts, in *Tacticks*, *Caſtrametation*, *Fortifying*, *Attacquing*, and *Defending*. The Ancients had more occaſion for Mechanicks in the Art of War than we have: Gun-powder readily producing a force far exceeding all the Engines, they had contriv'd for Battery. And this I reckon has loſt us a good occaſion of improving our Mechanicks: the cunning of Mankind never exerting it ſelf ſo much, as in their Arts of deſtroying one another. But, as Gun-powder has made Mechanicks leſs ſerviceable to War; it has made *Geometry* more neceſſary: There being a force or reſiſtance in the due meaſures and proportions of the Lines and Angles of a Fortification, which contribute much towards its ſtrength. This Art of *Fortification* has been much ſtudy'd of late, but I dare not affirm, that it has attain'd its utmoſt perfection. And tho', where the ground is regular, it admits but of ſmall variety, the meaſures being pretty well determined by *Geometry* and Experience, yet where the ground is made up of natural *Strengths* and *Weakneſſes*, it affords ſome ſcope for thinking and contrivance. But there is another much harder piece of *Geometry*, which Gun-powder has given us occaſion to improve, and that is the doctrine of Projectiles; whereon the Art of *Gunnery* is founded. Here the *Geometers* have invented a beautiful Theory, and Rules and Inſtruments, which have reduced the caſting of Bombs to great exactneſs. As for *Tacticks* and *Caſtrametation*, *Mathematicks* retain the ſame place in them as ever. And ſome tolerable skill in theſe is neceſſary for *Officers*, as well as for *Engineers*. An *Officer*, that underſtands Fortification, will *cæteris paribus* much better defend his poſt, as knowing, wherein its ſtrength conſiſts; or make uſe of his advantage to his Enemy's Ruine, than he that does not. He knows, when he leads never ſo ſmall a party, what his advantages and diſadvantages in Defending and Attacquing are, how to make the beſt of his Ground, *&c.* And hereby can do truly more ſervice than another of as much Courage, who, for want of ſuch knowledge, it may be, throws away himſelf and a number of brave Fellows under his Command: and it's well, if the miſchief reaches no further. As for a competent skill in *Numbers*, it is ſo neceſſary to *Officers*, that no Man can be ſafely truſted with a Company, that has it not. All the buſineſs is not to fire Muſquets; the managing of Affairs, the dealing with Agents, *&c.* happen more frequently. And the higher the Command is, the more skill in all the aforeſaid things is required. And I dare appeal to all the Nations in *Europe*, whether *cæteris paribus* Officers are not advanced in proportion to their skill in *Mathematical Learning*; except, that ſome times *Great Names* and *Quality* carry it; but ſtill ſo, as that the Prince depends upon a Man of *Mathematical Learning*, that is put as director to the *Quality*, when that Learning is wanting in it.

Laſtly, *Navigation* which is made up of *Aſtronomy* and *Geometry*, is ſo noble an Art, and to which Mankind owes ſo many advantages, that upon this ſingle account thoſe excellent Sciences deſerve moſt of all to be ſtudy'd, and merit the greateſt encouragement from a Nation, that owes to it both its Riches and Security. And not only does the Common Art of *Navigation* depend on *Mathematicks*, but whatever improvements ſhall be made in the *Architectura Navalis* or Building of Ships, whether they are deſign'd for Merchant-Ships, or Ships of War, whether ſwift running, or bearing a great Sail, or lying near the Wind be deſired, theſe muſt all be the Improvements of *Geometry*. *Ship-Carpenters* indeed are very Induſtrious; but in theſe things they acknowledge their inability, confeſs that their beſt Productions are the effects of chance, and implore the *Geometers* help. Nor will common *Geometry* do the buſineſs; it requires the moſt abſtruſe to determine the different ſections of a Ship, according as it is deſign'd for any of the aforeſaid ends. A *French* Mathematician *P. Le Hoſte* has lately endeavoured ſome thing in this way: and tho' it is not free from errors, as requiring a fuller knowledge in *Geometry*; yet is the Author much to be commended for this, as having bravely deſign'd, and pav'd the way for other Mathematicians; and alſo for the former and bigger part of his Book, wherein he brings to a ſyſtem the working of Ships, and the *Naval Tacticks*, or the regular diſpoſition of a Fleet in Attacquing,, Fighting and Retreating, according to the different circumſtances of Wind, Tides, &c.

The great objection, that is made againſt the neceſſity of *Mathematicks*, in the fore-mention'd great Affairs of *Navigation*, the Art *Military*, &c.

is, that we ſee thoſe Affairs are carry'd on and managed by ſuch, as are not great Mathematicians; as Sea-men, Engineers, Surveyers, Gaugers, Clock-makers, Glaſs-grinders, *&c.* and that the Mathematicians are commonly Speculative, Retir'd, Studious Men, that are not for an active Life and buſineſs, but content themſelves to ſit in their Studies, and pore over a *Scheme* or a *Calculation.* To which there is this plain and eaſy anſwer: The Mathematicians have not only invented and order'd all the Arts above-mentioned, by which thoſe grand Affairs are managed; but have laid down Precepts, contriv'd Inſtruments and Abridgments ſo plainly, that common Artificers are capable of practiſing by them, tho' they underſtand not a tittle of the grounds, on which the Precepts are built. And in this they have conſulted the good and neceſſities of Mankind. Thoſe Affairs demand ſo great a number of people to manage them, that it is impoſſible to breed ſo many good or even tolerable Mathematicians. The only thing then to be done was to make their Precepts ſo plain, that they might be underſtood and practiſed by a multitude of Men. This will beſt appear by examples. Nothing is more ordinary than diſpatch of buſineſs by common *Arithmetick*, by the *Tables of ſimple and compound Intereſt*, *Annuities*, &c. Yet how few Men of buſineſs underſtand the reaſons of common *Arithmetick*, or the contrivance of thoſe Tables, now they are made; but ſecurely rely on them as true. They were the good and the Thorough-Mathematicians, that made thoſe Precepts ſo plain and Calculated thoſe Tables, that facilitate the practice ſo much. Nothing is more univerſally neceſſary, than the meaſuring of Plains and Solids: And it is impoſſible to breed ſo many good Mathemathematicians, as that there may be one, that underſtands all the *Geometry* requiſite for Surveying, and meaſuring of *Priſms* and *Pyramids*, and their parts, and meaſuring *Fruſtums* of *Conoids* and *Spheroids*, in every Market-Town, where ſuch work is neceſſary: the Mathematicians have therefore inſcrib'd ſuch Lines on their common Rulers, and Slipping Rulers, and adapted ſo plain Precepts to them, that every Country-Carpenter, and Gauger, can do the buſineſs accurately enough; tho' he knows no more of thoſe Inſtruments, Tables, and Precepts he makes uſe of than a Hobby-horſe. So in *Navigation*, it is impoſſible to breed ſo many good Mathematicians, as would be neceſſary to ſail the hundredth part of the Ships of the Nation. But the Mathematicians have laid down ſo plain and diſtinct Precepts, Calculated neceſſary Tables, and contriv'd convenient Inſtruments, ſo that a Sea-man, that knows not the truths, on which his Precepts and Tables depend, may practice ſafely by them. They *reſolve* Triangles every day, that know not the reaſon of any one of their *Operations*. Sea-men in their Calculations make uſe of *artificial Numbers* or *Logarithmes*, that know nothing of their contrivance: and indeed all thoſe great Inventions of the moſt famous Mathematicians had been almoſt uſeleſs for thoſe common and great Affairs, had not the practice of them been made eaſy to thoſe who cannot underſtand them. From hence it is plain, that it is to thoſe *Speculative Retir'd Men*, we owe the Rules, the Inſtruments, the Precepts for uſing them, and the Tables which facilitate the diſpatch of ſo many great Affairs, and ſupply Mankind with ſo many conveniencies of Life. They were the Men, that taught the World to apply *Arithmetick*, *Aſtronomy*, and *Geometry* to *Sailing*, without which the Needle would be ſtill uſeleſs. Juſt the ſame way in the other parts of *Mathematicks*, the Precepts that are practiſed by multitudes, without being underſtood, were contriv'd by ſome few great *Mathematicians*.

Since then it has been ſhewn, how much *Mathematicks* improve the Mind, how ſubſervient they are to other Arts, and how immediately uſeful to the Commonwealth, there needs no other arguments or motives to a Government, to encourage them. This is the natural concluſion from theſe premiſes. *Plato* in his *Republick* (*lib.* VII.) takes care, *That, whoever is to be Educated for Magiſtracy, or any conſiderable Poſt in the Commonwealth, may be inſtructed firſt in Arithmetick, then in Geometry, and thirdly in Aſtronomy.* And however neceſſary thoſe Arts were in *Plato*'s time, they are much more ſo now: The Arts of War and Trade requiring much more the aſſiſtance of thoſe *Sciences* now, than they did then; as being brought to a greater height and perfection. And accordingly we ſee, theſe *Sciences* are the particular care of Princes, that deſign to raiſe the Force and Power of their Countries. It is well known, that this is none of the leaſt Arts, whereby the *French King* has brought his ſubjects to make that Figure at Sea, which they at this time do; I mean, the care He takes for Educating thoſe appointed for Sea-ſervice in *Mathematical Learning*. For in the *Ordonnance Marine*, *Title* VIII. 'He orders, that there be Profeſſors 'to teach Navigation publickly in all the Sea-port 'Towns, who muſt know *deſigning*, and teach it 'to their Scholars, in order to lay down the ap'pearances of Coaſts, *&c.* They are to keep 'their Schools open, and read four times a week 'to the Sea-men, where they muſt have Charts, ‘Globes, Spheres, Compaſſes, Quadrants, Aſtrolabes, and all Books and Inſtruments neceſſary to teach their Art. The directors of Hoſpitals are oblig'd to ſend thither yearly two or three of their boys to be taught, and to furniſh them with Books and Inſtruments. Thoſe Profeſſors are oblig'd to examine the Journals depoſited in the Office of Admiralty, in the place of their eſtabliſhment; to correct the errors in preſence of the Sea-men, and to reſtore them within a month, *&c.* King *Charles* the ſecond, who well underſtood the importance of Eſtabliſhments of this nature, founded one ſuch School in *Chriſt's Hoſpital London*; which, I believe, is inferiour to none of the *French*: but 'tis to be wiſhed there were many more ſuch. His preſent *Majeſty*, during the time of the late War, eſtabliſhed a *Mathematical Lecture* to breed up Engineers and Officers, as knowing very well the importance thereof. And this continued ſome time after the *Peace*. And it is worthy the conſideration of the *Wiſdom* of the Nation, whether the reſtoring and continuing this, even in *Peace*, be not expedient for the breeding of Engineers, who are ſo uſeful and valuable, and ſo difficult to be had in time of War, and ſo little dangerous in times of *Peace*.

Beſides the crowd of *Merchants*, *Sea-men*, *Surveyors*, *Engineers*, *Ship-carpenters*, *Artiſans*, &c. that are to be inſtructed in the practice of ſuch parts of *Mathematicks*, as are neceſſary to their own buſineſs reſpectively, a competent number of *able Mathematicians* ought to be entertained, in order to apply themſelves to the practice; not only to inſtruct the former ſort, but likewiſe to remove thoſe obſtacles, which ſuch, as do not think beyond their common Rules, cannot overcome. And no doubt it is no ſmall impediment to the advancement of Arts, that *Speculative Men* and *good Mathematicians* are unacquainted with their particular defects, and the ſeveral circumſtances in them, that render things *practicable* or *impracticable.* But if there were publick encouragement, we ſhould have skilful Mathematicians employed in thoſe Arts, who would certainly find out and remedy the imperfections of them. The preſent Lords Commiſſioners of the Admiralty knowing, that there are ſtill two great *Deſiderata* in Navigation, to wit, *The Theory of the variation of the magnetical Needle*, and a *method of finding out the Longitude of any place*, that may be practicable at Sea by Sea-men, and being ſenſible, of what importance it would be to find out either of them, have imployed a very fit perſon, the ingenious Mr. *Hally*, who has joyn'd an entire acquaintance in the practice, to a full and thorough knowledge of the more abſtruſe parts of *Mathematicks.* And now that he is returned, it is not doubted, but he will ſatisfy thoſe, that ſent him, and in due time the World too with his diſcoveries in both thoſe particulars, and in many other, that he has had occaſion to make. And where a long ſeries of Obſervations and Experiments is neceſſary, he has no doubt laid ſuch a foundation, as that After-Obſervers may gradually perfect them. If it were not for more than the correcting the ſituation of the Coaſts, where he touched, and by them others, whoſe relation to the former is known, the Nation is more than triply pay'd: and thoſe, who ſent him, have by this Miſſion ſecured to themſelves more true Honour and laſting Fame, than by Actions, that at firſt view appear more Magnificent.

The next thing, that is neceſſary for the improvement of *Mathematical Learning*, is, That Mathematicks be more generally ſtudy'd at our *Univerſities* than hitherto they have been. From thoſe Seminaries the State juſtly expects and demands thoſe, who are acquainted both with the *Speculation* and *Practice*. In thoſe are all the encouragements to them imaginable, Leiſure and Aſſiſtance. There are ſtill at hand Books and Inſtruments, as alſo other Scholars that have made equal progreſs, and may be Comrades in ſtudy, and the direction of the Profeſſors. There are alſo in perfection all the incitements to this ſtudy, and eſpecially an acquaintance with the works of the Ancients, where this *Learning* is ſo much recommended: There other Faculties are ſtudy'd, to which it is ſubſervient. There alſo are the Nobility and Gentry bred, who, in due time muſt be called to their ſhare in the Government of the *Fleets*, *Army*, *Treaſury*, and other Publick Employments, where *Mathematical Learning* is abſolutely neceſſary, and without which, they, tho' of never ſo great Natural parts, muſt be at the mercy and diſcretion of their Servants and Deputies; who will firſt cheat them, and then laugh at them. And not only Publick Employments, but their Private Concerns demand Mathematical knowledge. If their Fortunes lie in Woods, Coal, Salt, Manufactures, *&c.* the neceſſity of this knowledge is open and known: and even in Land-Eſtates, no undertaking for improvement can be ſecurely rely'd upon without it. It not only makes a Man of Quality and Eſtate his whole Life more Illuſtrious, and more uſeful for all Affairs, (as *Hippocrates* ſays, Ἱστορίης δὲ μελέτω σοὶ ὦ παῖ, Γεωμετρικῆς ϗ Ἀριθμητικῆς· οὐ γὰρ μόνον, σέο ϗ τὸν βίον εὐκλέα ϗ ἐπὶ πολλὰ χρήσιμον ἐς ἀνθρωπίνην μοίρην [illegible], ἀλλὰ καὶ τὴν ψυχὴν ἐξεγείρειν τε καὶ ἀναζωπυρεῖν, &c.) but in particular, it is the beſt Companion for a Country Life. Were this once become a faſhionable ſtudy (and the *Mode* exerciſes its Empire over Learning as well as other things) it is hard to tell, how far it might influence the Morals of our Nobility and Gentry, in rendring them Serious, Diligent, Curious, taking them off from the more fruitleſs and airy exerciſes of the Fancy, which they are apt to run into.

The only Objection, I can think of, that is brought againſt theſe ſtudies, is, that Mathematicks require a particular turn of Head, and a happy Genius that few people are Maſters of, without which all the pains beſtowed upon the ſtudy of them are in vain: They imagine that a *Man muſt be born a Mathematician.* I anſwer, that this *Exception* is common to Mathematicks and other Arts. That there are perſons, that have a particular capacity and fitneſs to one more than another, every body owns: And from experience I dare ſay, it is not in any higher degree true concerning Mathematicks than the others. A Man of good ſenſe and application is the Perſon, that is by nature fitted for them: eſpecially if he begins betimes: And if his circumſtances have been ſuch, that this did not happen, by prudent direction the defect may be ſupply'd as much as in any Art whatſoever. The only advantage this Objection has, is, that it is on the ſide of ſoftneſs and idleneſs, thoſe powerful Allies.

There is nothing further remains, Sir, but that I give you my thoughts in general concerning the *Order* and *Method* of ſtudying *Mathematicks*; which I ſhall do very ſhortly, as knowing that you are already acquainted with the beſt methods, and others with you may have them eaſily from the beſt and ableſt hands.

Firſt then, I lay down for a principle, that no body at an *Univerſity* is to be taught the practice of any rule without the true and ſolid reaſon and demonſtration of the ſame. Rules without demonſtration muſt and ought to be taught to *Sea-men*, *Artiſans*, &c. as I have already ſaid; and Schools for ſuch people are fit in Sea-ports and Trading-Towns; but it is far below the dignity of an *Univerſity*, which is deſign'd for ſolid and true Learning, to do this. It is from the Univerſities, that they muſt come, who are able to remedy the defects of the Arts; and therefore nothing muſt be taken on truſt there. *Sea-men*, and *Surveyors*, &c. remember their Rules, becauſe they are perpetually practiſing them: But *Scholars*, who are not thus employ'd, if they know not the demonſtration of them, preſently forget them.

Secondly, no part of Mathematicks ought to be taught by *Compendiums*. This follows from the former. *Compendiums* are fit to give a general and ſuperficial knowledge, not a thorough one. It's time, and not the bulk of Books, we ought to be ſparing of: And I appeal to any perſon of Experience, whether ſolid knowledge is not acquir'd in ſhorter time by Books treating fully of their ſubjects, than by Compendiums and Abridgments.

From hence it follows, that the *Elements* of *Arithmetick* and *Geometry* are to be taught. *Euclid* in his thirteen Books of Elements gives us both: but our preſent way of Notation ſuperſedes ſome of thoſe of *Arithmetick*, as demonſtrating the Rules from the Operations themſelves. There remain then the firſt ſix Books for the *Geometry* of *Plains*, and the laſt three for *Stereometry*. The reſt ought to be read in their own Place for the perfection of *Arithmetick*. In teaching theſe, care ought to be taken to make uſe of ſuch Examples, as ſuit

with

with the condition of the Scholar. For inſtance, *Merchants Accounts* and *Affairs* for Examples of the Operations of *Arithmetick*, to one that is afterwards to have a concern that way; whereas to a Man of the firſt Quality, examples from *the encreaſe* and *decreaſe of the people*, or from *Land or Sea-Force*, and from the *Tacticks* ought to be propoſed. For it is certain, nothing makes one tir'd ſooner, than the frivolous and trifling examples, that are commonly brought for the exerciſe of the Rules of *Arithmetick* and *Geometry*: tho' this is common to them with the other Arts, as *Grammar*, *Logick*, &c.

The manner of Writing of the Mathematicians of this and the former Age makes *Trigonometry*, with the manner of conſtructing its Tables, *&c.* almoſt *Elementary*; and the *Practical Geometry* commonly ſo call'd, is very fit to come next, as an elegant application of the *Elements* of *Geometry* to Buſineſs, as *Surveying*, *Gauging*, &c.

After the Elements of *Sphericks*, which are perfectly well handled by *Theodoſius*, a full inſight into the principles of *Aſtronomy* will be neceſſary.

Mechanicks come next to be read, which are the Ground of a great part of Natural Learning: and afterwards *Opticks*, *Catoptricks* and *Dioptricks*.

But none of theſe except the Elements can be fully underſtood until one is pretty well skill'd in *Conick-Sections*: And all theſe are made more eaſy by ſome tolerable skill in *Algebra*, and its application to *Geometry*.

Theſe foundations being laid, any one may with great eaſe purſue the ſtudy of the Mathematicks, as his occaſions require: either in its abſtract parts, and the more *recondite Geometry*, and its application to Natural knowledge; or in

Mechanicks, by proſecuting the *Staticks*, *Hydroſtaticks*, *Balliſticks*, &c. or in *Aſtronomy*, by its application to *Geography*, *Navigation*, *Gnomonicks*, *Aſtrolabes*, &c. But in moſt of theſe a particular order is not neceſſary. Any one may take that firſt, which he is moſt inclined to.

I ſhall not offer you any advice concerning the choice of Books, but refer you (if you want any) to the direction of thoſe, who are Eminent among you in this part of Learning. I ask your pardon for the omiſſion of *Ceremony* in theſe papers, having followed rather the ordinary way of *Eſſay* than *Letter*: and wiſhing you good ſucceſs in your ſtudies, I am,

SIR,

Your Friend and Servant.

25. *Novemb.*
1700.

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